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MODELING OF FREQUENTIS CHARACTERISTICS OF RESONATOR SYSTEM OF POWERFUL KLYSTRON WITH THE MELTING OF THE TRANSIENT CHANNELS

Annotation. *The idea of regeneration of powerful microwave devices arose in the 50's of the last century. As the experience of profile enterprises of Ukraine shows, in most cases only the replacement of a cathode unit is performed during regeneration. However, in order to decide on the suitability of the device for regeneration, it is necessary to make a defect of the structure to match the TC. The paper presents the results of modeling the influence of mechanical defects on the state of the resonator system of a powerful klystron and their numerical impact assessment. The principal possibility of performing the diagnostics of the construction of microwave devices on the subject of its suitability for regeneration by non-destructive methods with localization of the defect in the constructionis shown.*

Keywords*: klystron, construction's defect, diagosmic microwave devices.*

Introduction

The analysis of works devoted to the regeneration of high-power microwave devices [1,2] shows that the constructive and technological complexity of such devices led to the establishment of the concept of restoration, which reduces to the dismantling of the device that has refused, on separate гтшеes, while deflecting defective, are suitable for reuse in other devices of the same type.As shown by the analysis of the data of the defect of devices made on the State Enterprise plant "Generator", suitable for regeneration, there are about 55% of the devices provided by the customer.With such a high percentage of defective devices and the use of manual disassembly of elements, the process of defect becomes a source of non-productive technological costs.In this connection, the task of optimizing the process of defect in terms of exclusion from the technological cycle of the defect of unprofitable operations and increasing the accuracy and speed of diagnosis.One of the possible solutions may be the creation and use of diagnostic methods that would not require manual disclosure of the device.Such methods can be, for example, cold measurements of electrodynamic parameters of resonator units or the method of scanning probe microscopy for surface control.In the analysis of the main reasons for the device to be regenerated, it was discovered that the main reasons are: melting of transmitted channels; flow of liquid from the cooling system; sputtering at the cathode pole in the vicinity of transmitted channels; scale on the internal surfaces of the resonator system, etc. One of the common defects ofunits (about 25%) in the interior vacuum cavity is the melting of transmitted channels of resonators. Therefore, it is expedient to start work on simplifying the process of defect, namely, on the development of methods for detecting this defect by non-destructive methods.

Experiment technique

As can be seen from Figure 1, the electronic stream must pass from the cathode through the lattice, the flowing channels of the resonators and settled on the anode. Whether its deviation is inadmissible and entails a number of negative consequences such as changing the output parameters, melting in the construction, and others.

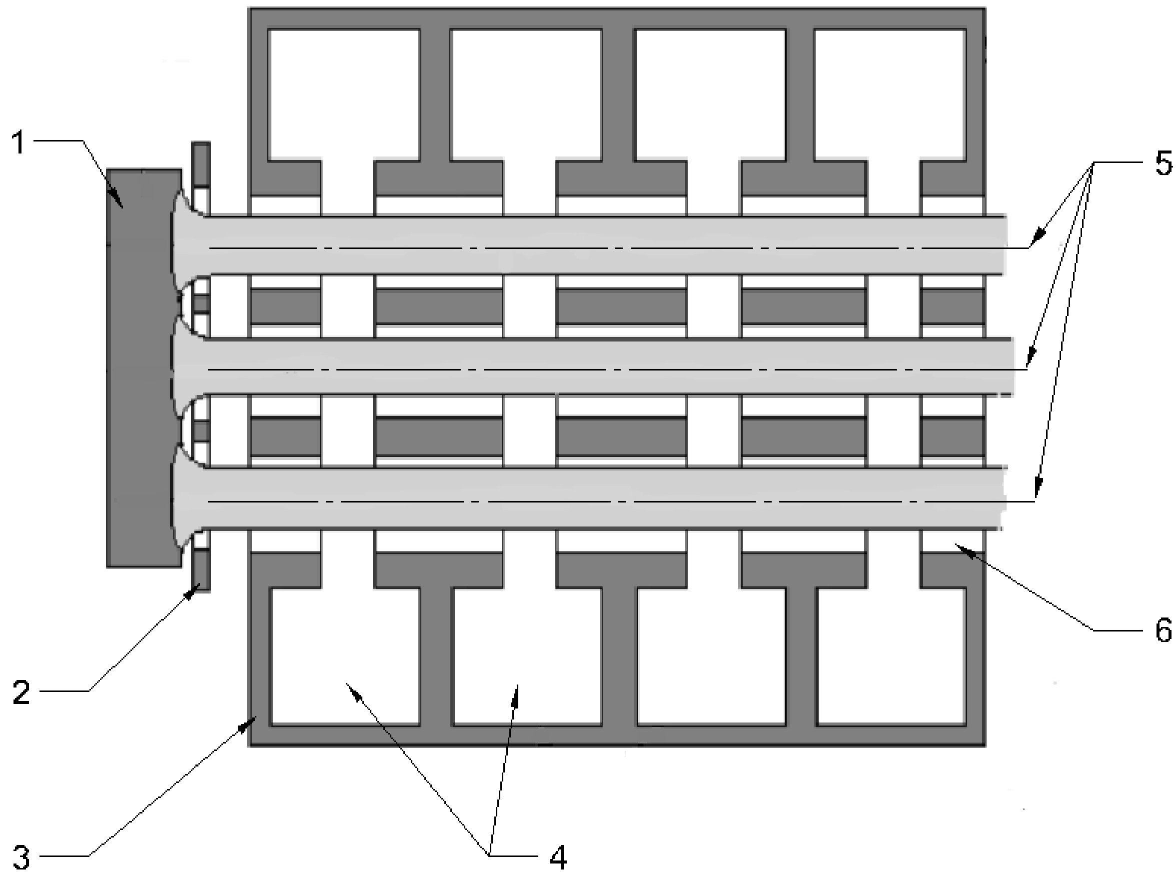

Figure 1 – Idealized klystron scheme. 1 - cathode, 2 - lattice, 3 - anode, 4 - resonators, 5 - electronic bundles, 6 - transmitted channels..

Since the acquisition of real devices for research is associated with a number of difficulties, then for the study of the effect described above defects, the resonator system of klystron (Figure 1) built its simulation model in an HFSS Ansoft [3] environment with characteristics Q_0= 133,

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fрез =0,915 ГГц. . The walls of the resonator were considered to be perfectly conducting surfaces. Its frequency is shown in Figure 2.

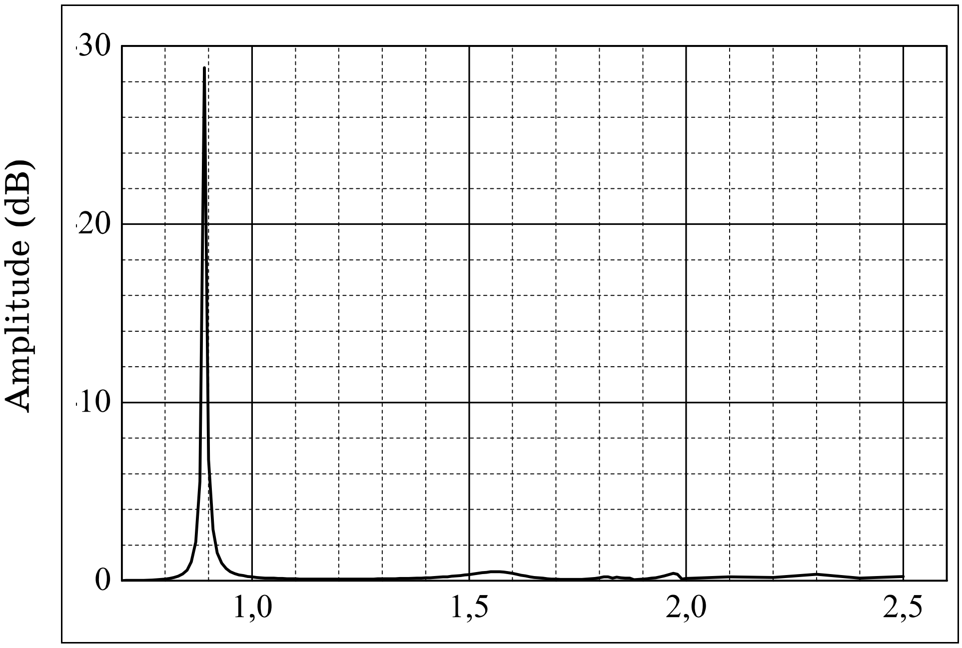

Figure2 – AFCmodels of the resonator systemof a powerful klystron.

Effect of melting on the frequency response of the resonant system

Melting in the resonator system leads to a change in its geometry. They have a cylindrical shape. As is known, [4] the resonator is part of the space bounded by a metal wall. Since the form of the defect is close to the cylindrical one, the defect itself can be regarded as a cylindrical cavity resonator attachedto the resonator system of the microwave device.For resonances of E-waves in a cylindrical resonator there is [5]:

$$(\lambda_0)_{\mathrm{E}} = \frac{1}{\sqrt{\left(\frac{\nu_{ni}}{2\pi R}\right)^2 + \frac{p^2}{4l^2}}} \quad (1);$$

Where$R$ – inner cylinder radius and$l$ – its height.he numbers n, i, p, determine respectively the field variation along the azimuth, radius and height of the resonator.By$\nu_{ni}$the$i$-throot of the bessel function of the first kind of the n-th order is indicated.

Resonances of type H waves in a cylindrical resonator are determined by the relation:

$$(\lambda_0)_H = \frac{1}{\sqrt{\left(\frac{\mu_{ni}}{2\pi R}\right)^2 + \frac{p^2}{4l^2}}} \quad (2);$$

Byμ_{ni} the$i$-throot of the bessel function of the first kind of the n-th order is indicated

Since R i l parameters of the resonator defect are much smaller than the characteristic dimensions of the resonance system, then its resonant wavelength will also be much smaller. At the frequency response of the resonator system this will be manifested in the form of harmonicappearance.

Results of modeling

In order to generate an electromagnetic field solution, HFSS employs the finite element method[6]. In general, the finite element method divides the full problem space into thousands of smaller regions and represents the field in each sub-region (element) with a local function.

In HFSS, the geometric model is automatically divided into a large number of tetrahedra, where a single tetrahedron is a four-sided pyramid. This collection of tetrahedra is referred to as the finite element mesh. For the model, the following parameters were set: band frequency 0,7..2,5GHz, step 10 MHz, maximum number of passes 10.

The results of the analysis of modelconstructionare shown in Figure 2. The next step was to attached changes to the constructionof the resonator model to simulate the melting of the transmitted channels. For this purpose, a cylinder was placed on the resonator wall and its radius R, length l and location in the structure of the resonator were varied and fixed as the frequency response of the system.

As you can see from Figure 3,for$R_1$the average harmonics ranges from 2.5 to 5dB. However, it is clearly visible that the peak reaches 10 dB and corresponds to the resonance frequency of the defect.

With an increase in R_1toR_2 , as expected, the resonance frequency of the defect began to decrease and the division of harmonics into groups around two peaks at 15 dB.

Finally with R_3, which was the maximum value of the radius of the defect, formed three groups of harmonics around clearly defined peaks.

As can be seen from Figures 3.4, 5, the attached of a defect has little effect on the resonance frequency of the system, but causes the appearance of harmonics $f_h$and a decrease in the amplitude at the resonant frequency.As we see in the vicinity of the same frequencies there are harmonics families of different amplitudes, which depends on the position of the defect in the construction. Thus we can talk about the possibility of defect localization in the construction by analyzing the frequency response of the system.

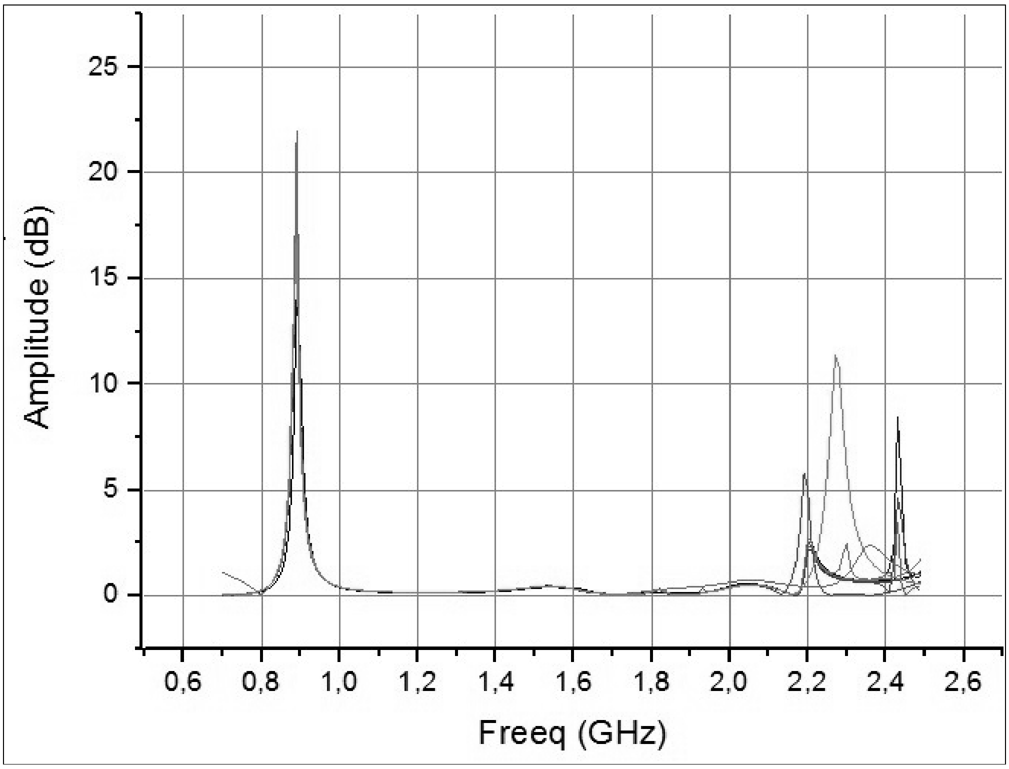

Figure 3 – AFC model of a resonator system of a powerful klystron with a defect's volume of 1% of the volume of the resonator.

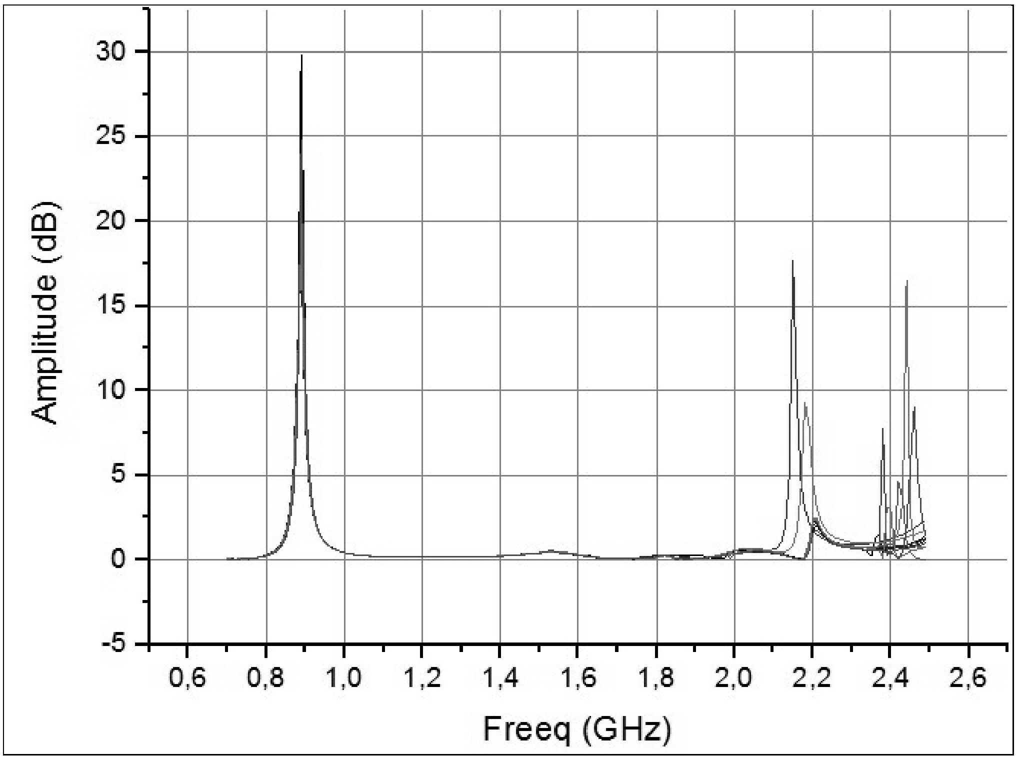

Figure 4 – AFC model of a resonator system of a powerful klystron with a defect's volume of 3% of the volume of the resonator.

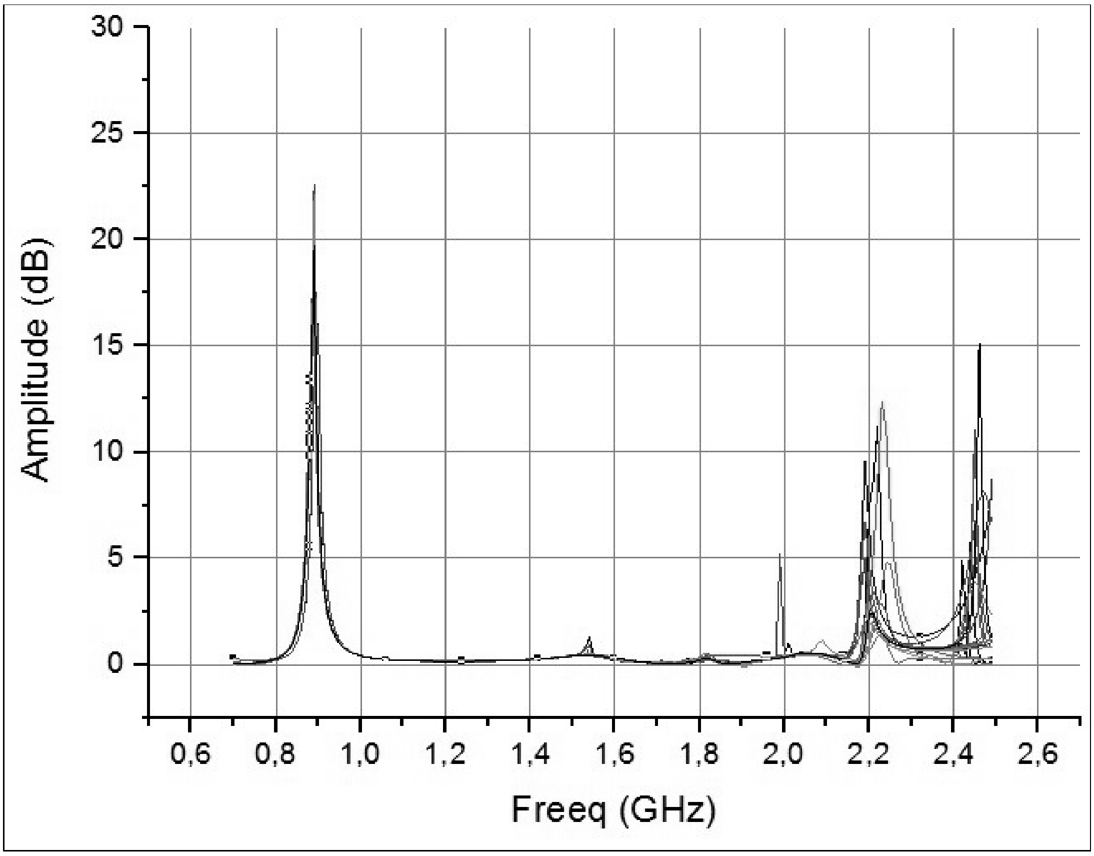

Figure 5 – AFC model of a resonator system of a powerful klystron with a defect's volume of 5% of the volume of the resonator.

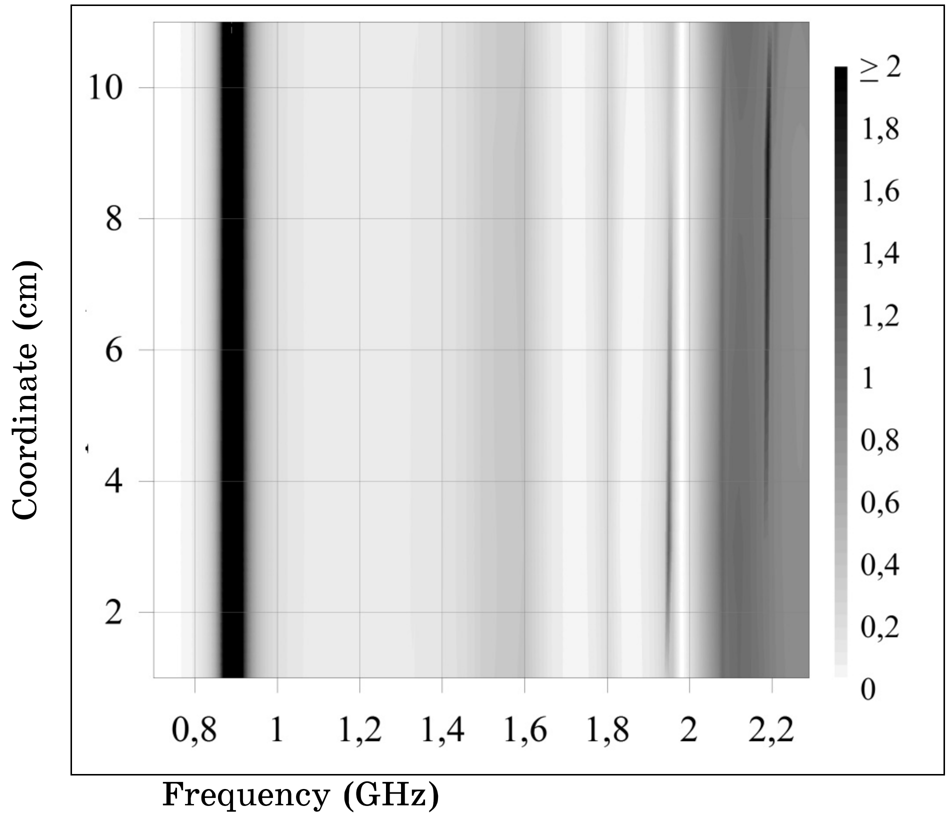

Figure6 – An example of defect localization in a construction.

As we can see from Figure 6, the attached of a defect causes the expansion of the spectrum line in the range of 0.8-1 GHz, indicating a small displacement of the resonant frequency of the model. Lines at frequencies close to 1.95 GHz and 2.2 GHz reflect harmonics caused by a defect. As you can see, the gradation of the color of these lines depends on the position of the defect in the construction, which makes it possible to localize it.

Returning to formulas 1 and 2, knowing harmonics frequencies becomes an interesting inverse problem - finding the parameters R and l of a cylindrical resonator, which will allow us to estimate the magnitude of the defect and obtain more data for making a decision about the state of the system in general.

Conclusions

- A hypothesis was made about the possibility of detecting the melting of transmitted channels in the resonator system of the klystron by measuring the frequency response of normal and defective devices. To test the hypothesis, an imitation model of the resonator system was constructed. It is now possible to identify and locate the structural defect in the resonator system of the klystron in the form of melting.
- A set of AFCs for systems with defects with volume from 1 to 5% of the resonator volume is obtained, and the numerical values of the harmonics amplitudes when variations in the size of the defect and its position in the structure.

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